

AD-A204 798

REPORT DOCUMENTATION PAGE

2b. DECLASSIFICATION/DOWNGRADING SCHEDULE			1b. RESTRICTIVE MARKINGS 9116 FILE C-1			
4. PERFORMING ORGANIZATION REPORT NUMBER(S)			3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution is unlimited.			
6a. NAME OF PERFORMING ORGANIZATION Naval Ocean Systems Center		6b. OFFICE SYMBOL (if applicable) NOSC	7a. NAME OF MONITORING ORGANIZATION Naval Ocean Systems Center			
6c. ADDRESS (City, State and ZIP Code) San Diego, CA 92152-5000			7b. ADDRESS (City, State and ZIP Code) San Diego, CA 92152-5000			
8a. NAME OF FUNDING/SPONSORING ORGANIZATION Naval Ocean Systems Center		8b. OFFICE SYMBOL (if applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER			
8c. ADDRESS (City, State and ZIP Code) Block Programs San Diego, CA 92152-5000			10. SOURCE OF FUNDING NUMBERS			
			PROGRAM ELEMENT NO. 62234N 61152N	PROJECT NO. EEB3 ZT83	TASK NO.	AGENCY ACCESSION NO. DN313 033 DN308 081
11. TITLE (include Security Classification) FORMATION AND ANALYSIS OF SHALLOW ARSENIC PROFILES						
12. PERSONAL AUTHOR(S) S. R. Clayton						
13a. TYPE OF REPORT Paper		13b. TIME COVERED FROM July 1988 TO July 1988		14. DATE OF REPORT (Year, Month, Day) November 1988		15. PAGE COUNT
16. SUPPLEMENTARY NOTATION						
17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)			
FIELD	GROUP	SUB-GROUP	ION beam technology ; electronic devices, components and subsystems			
19. ABSTRACT (Continue on reverse if necessary and identify by block number) Shallow arsenic implants were activated by furnace and rapid thermal annealing (RTA). Comparisons of junction depths measured by secondary ion mass spectrometry (SIMS) and spreading resistance (SR) showed SIMS values 50-90 nm deeper than SR values, due to ion knock-on during SIMS profiling.						
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT <input type="checkbox"/> UNCLASSIFIED/UNLIMITED <input checked="" type="checkbox"/> SAME AS RPT <input type="checkbox"/> DTIC USERS						
21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED						
22a. NAME OF RESPONSIBLE PERSON S. R. Clayton			22b. TELEPHONE (include Area Code) (619) 553-3909		22c. OFFICE SYMBOL Code 553	

Published in Electronics Letters, 7 July 1988, Vol. 24, No. 14.

DTIC
ELECTE
S 4 FEB 1989 D
E

FORMATION AND ANALYSIS OF SHALLOW ARSENIC PROFILES

Indexing terms: Semiconductor devices and materials, Semiconductor doping, Ion implantation, Annealing

Shallow arsenic implants were activated by furnace and rapid thermal annealing (RTA). Comparisons of junction depths measured by secondary ion mass spectrometry (SIMS) and spreading resistance (SR) showed SIMS values 50-90 nm deeper than SR values, due to ion knock-on during SIMS profiling.

As device geometries become smaller, ever shallower junctions are required for both MOS and bipolar transistors. RTA is used for shallow junction formation since it activates dopants with minimal dopant diffusion. However, accurate determination of junction depths of 150 nm or less can be difficult. In this letter we compare shallow n^+/p junctions formed by RTA and furnace annealing as measured by SIMS and SR. SIMS

831



Accession For	
NTIS GRA&I	<input checked="" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By _____	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	20

and SR were compared to determine which provides more accurate junction depths and doping profiles for high concentration, shallow junctions. Previous comparisons between SIMS and SR for furnace-annealed arsenic implants with relatively deep junctions have been made.¹⁻² Naem and Calder³ have examined shallow junctions ($<0.2\ \mu\text{m}$) activated by both furnace annealing and RTA; their results will be compared to the present work.

Eleven three-wafer sets of $10\text{--}18\ \Omega\text{cm}$ p -type Si wafers were implanted with an arsenic dose of $2 \times 10^{15}\ \text{cm}^{-2}$ at $45\ \text{keV}$ through $20\ \text{nm}$ of SiO_2 . The wafers were annealed as shown in Table 1. The RTAs were performed using AG Associates

Table 1 ANNEAL CONDITIONS FOR EACH WAFER SET

Set	Type of anneal
FURN	15 min 900°C furnace anneal
FURN+	15 min 900°C , furnace anneal plus furnace processing*
YKT1	3 s 1100°C RTA at IBM Yorktown
YKT2	10 s 1100°C RTA at IBM Yorktown
YKT2+	10 s 1100°C RTA at IBM Yorktown plus furnace processing
YKT3	30 s 1100°C RTA at IBM Yorktown
NOSC1	3 s 1100°C RTA at NOSC
NOSC2	10 s 1100°C RTA at NOSC
NOSC2+	10 s 1100°C RTA at NOSC plus furnace processing
NOSC3	30 s 1100°C RTA at NOSC

* Furnace processing: 5 min 900°C n^+, p^+ drive-in and 30 min 800°C LTO PSG anneal

Heatpulse 410 systems at NOSC and at IBM, Yorktown, and are labelled accordingly. Wafer sets which received further high-temperature processing to simulate normal post-implant furnace steps are labelled with a '+'.

Following the anneals the SiO_2 was stripped, and SR and SIMS measurements were made on each wafer. For the SR measurements, the samples were bevelled to a nominal angle of 8° . Bevel angles were measured by the standard dual wire image technique⁴ and corroborated by measurement of spot separation of a laser reflected off the two surfaces; junction depth accuracy was $\pm 20\ \text{nm}$. For the SIMS measurements, caesium was used as the primary ion source for increased arsenic sensitivity to the mid $10^{16}\ \text{cm}^{-3}$ range. Junction depths were estimated from the SIMS curves by a linear extrapolation of the SIMS profile down to $10^{16}\ \text{cm}^{-3}$.

Junction depths measured by SIMS and SR are shown in Fig. 1. SIMS gave extrapolated junction depths 50–90 nm

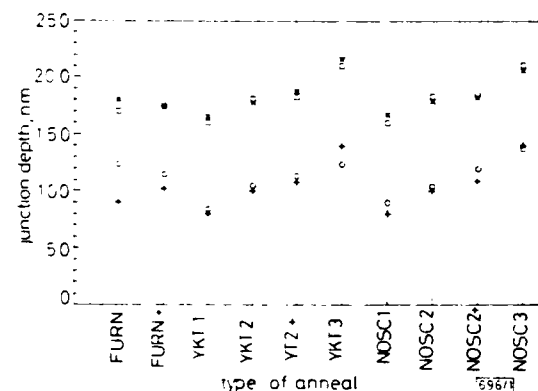


Fig. 1 Junction depths for different processing conditions

- × × × SIMS
- ○ ○ SR
- + + + computer model
- □ □ computer model with 25 nm/decade tail

greater than the values given by SR. Most of this discrepancy is believed to be caused by ion knock-on during SIMS profiling,⁵ an effect increased by using caesium instead of oxygen as the sputtering ion. Ion knock-on adds a resolution tail to the SIMS profile and is mainly important for profiles with rapid concentration decreases. We observed an average slope

of 25 nm/decade, similar to the 28 nm/decade slope measured on abrupt arsenic profiles grown by molecular beam epitaxy.⁶

As further evidence that the observed tails are an artefact of SIMS, Fig. 2 compares profiles made using caesium and

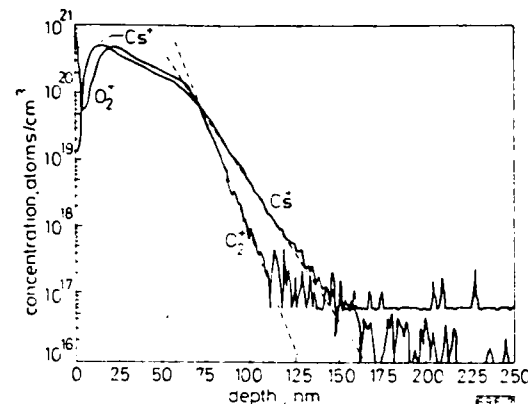


Fig. 2 SIMS data using Cs^+ and O_2^+ beams

RTA, 1100°C , 3 s

oxygen beams. The junction depth measured using oxygen is 40 nm shallower than that using caesium and the slope steepens to 14 nm per decade due to reduced ion mixing. This difference in junction depth and slope was observed in all samples analysed by both caesium and oxygen profiling. While use of the lighter oxygen ion reduces arsenic knock-on, it also reduces the arsenic sensitivity of SIMS, as seen in the higher background level of the O_2^+ profile.

Similar discrepancies between SIMS and SR have been noted³ but have been attributed to carrier spilling in SR described by Hu.⁶ However, extrapolations of carrier spilling to the profiles in the present work only account for at most half of the SIMS-SR discrepancy. We conclude that while carrier spilling is a factor in our SR measurements, ion knock-on in SIMS is an equal or greater contributor to the junction depths differences.

Finally, computer modelling⁷ of these processes was used to predict junction depths for the samples. The predicted values for RTA and furnace anneals are within 15 and 35 nm, respectively, of the SR values (Fig. 1). Also shown are junction depth values predicted by limiting the rolloff of the computer model profiles to 25 nm/decade. These values are in good agreement with the SIMS values. Based on these results, we use the SR data for discussion of junction depths.

The three and ten second RTAs produced junction depths less than those produced by the furnace anneals. Longer RTAs caused increased junction depths. Subsequent high-temperature processing had little effect on the junction depths of the furnace annealed samples, but slightly increased them for the RTA samples.

Shallow arsenic implants were activated by conventional furnace processing and by RTA. Two techniques for measuring high concentration shallow junction depths, SIMS and SR, were compared. SIMS gave junction depth values 50–90 nm greater than those given by SR. This discrepancy is believed to be caused by the ion knock-on produced by SIMS. RTAs of 1100°C for ten seconds and less produced shallower junctions than furnace anneals of 900°C for 30 minutes.

The authors would like to thank I. Lagnado for his support and M. Polavarapu for his useful discussions.

S. CLAYTON*
L. SPRINGER†
B. OFFORD*
T. SEDGWICK*
R. REEDY*
A. MICHEL*
G. SCILLA*

* Naval Ocean Systems Center
San Diego, CA 92152-5000, USA

† IBM Federal Systems Division
Manassas, VA 22110, USA

* IBM T. J. Watson Research Center
Yorktown Heights, NY 10598, USA

§ SCILLA, G.: To be published

24th May 1988

References

- 1 ALBERS, J., ROITMAN, P., and WILSON, C. W.: 'Verification of models for fabrication of arsenic source-drains in VLSI MOSFET's', *IEEE Trans.*, 1983, **ED-30**, pp. 1453-1462
- 2 GODFREY, J. D., GROVES, R. D., DOWSETT, M. G., and WILLOUGHBY, A. F. W.: 'A comparison between SIMS and spreading resistance profiles for ion implanted arsenic and boron after heat treatments in an inert ambient', *Physica*, 1985, **129B**, pp. 181-186
- 3 NAEM, A. A., and CALDER, I. D.: 'Formation of shallow n^+p junctions', *J. Appl. Phys.*, 1987, **62**, pp. 569-575
- 4 DEINES, J. H., GOREY, E. F., MICHEL, A. E., and POPONTAK, M. R.: 'Preparation of a lightly loaded, close-spaced spreading resistance probe and its application to the measurement of doping profiles in silicon', NBS Special Publication 400-10 (U.S. Government Printing Office, Washington, 1974), pp. 169-178
- 5 TURNER, J. E., AMANO, J., GRONET, C. M., and GIBBONS, J. F.: 'Secondary ion mass spectrometry of hyper-abrupt doping transitions fabricated by limited reaction processing', *Appl. Phys. Lett.*, 1987, **50**, pp. 1601-1603
- 6 HU, S. M.: 'Between carrier distributions and dopant atomic distribution in beveled silicon substrates', *J. Appl. Phys.*, 1982, **53**, pp. 1499-1510
- 7 TSAI, M. Y., MOREHEAD, F. F., BAGLIN, J. E. E., and MICHEL, A. E.: 'Shallow junctions by high-dose As implants in Si: Experiments and modeling', *J. Appl. Phys.*, 1980, **51**, pp. 3230-3235